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Mathematical modell used in decision-making process with respect to the reliability of geo database

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Abstract

The University of Defence (UoD) plays the key role of the Czech military professional personnel university-level education and of the science research within the Ministry of Defence. Education and research are therefore the school's priorities, completed with expert and processing work. The authors of the contribution have participated for many years on the educational process of bachelor's and master's studies at the Faculty of Military Technologies of UoD, for daily and combined form of the study as well as in the research projects. The aim of this contribution is to explore how we might better understand geospatial data using sophisticated analysis tools, to introduced some delightful equations to give objective rigor to otherwise subjective guesswork and to show how we could bring a degree of robustness of analysis to the selection of a route by measuring the complexity of the terrain and the ability of the Czech Army trucks to navigate such routes, as well as to find the possible way how this task gaining from praxis can be integrated into teaching process.

Keywords: Entrance exam from mathematics, development of human resources;

1. Introduction

1.1. University scope

The University of Defence (UoD) takes an irreplaceable role of the Czech military professional personnel university-level education and of the science research within the Ministry of Defence. Education and research are therefore the school's priorities, completed with expert and processing work. University provides education in bachelor, master, doctoral degree programmes and the follow-on training (organized in life education programmes in the forms of career purpose and special courses of post-gradual nature).

The University is responsible for education of military professionals and other experts engaged in national security and defense. Education is based on the latest knowledge, research and development in both national and international scales and internal research to provide for wide and general graduate profiles for their better assertion and career promotion under variable conditions of military environment. The versatile education enables the University graduates a better position also in civilian life. The department of Military Geography and Meteorology

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exists solely to service Army decision makers–at all levels. Except educational process, the role of the department is as that of providing clarity to the battlespace – the Recognised Environmental Picture (REP), by being dynamic to reflect both environmental changes, brought about by weather for example and human changes, wrought by enemy action, infrastructure building or destruction. It focused on the issue of the quality of data, whether technical, functional, safety, etc and needing to know its validity, when last updated, positional accuracy, completeness of data, etc.

1.2. Changes in contents of education

During last years the most significant changes occurs in the contents of education, new educational and study programs have been accredited, reflecting current needs of the Czech Republic's Army.

The quality of education and training readiness of career soldiers have increased substantially. Nowadays, highly educated, recognized and first class specialists in their fields graduate from military schools, otherwise unable to receive similar education and training of the same quality elsewhere. A big amount of graduates from foreign military schools contributes to it too. The department specializes in application of geographic, meteorological and surveying sciences into the ACR's and NATO's geographic and hydrometeorological security systems. Its specialization closely draws on a number of scientific and technical disciplines such as geography, military geography, geoinformatics, cartography, photogrammetrics and Earth remote survey, synoptic meteorology, climatology, atmosphere physics, satellite and radiolocation meteorology, atmosphere chemism, geodesy, geophysics and global navigation systems.

1.3. Research

Research includes particularly task solving in defence research and crises management and responding to current problems connected to applying geoinformatic technologies into command and control systems and simulation of atmospheric processes for giving precision to weather forecasts. The department also conducts research related to the influence of terrain and hydrometeorological conditions on the activity of armed forces, application of satellite methods for dangerous meteorological phenomena forecasts, application of global navigation systems for positional service within the ACR. The department also takes part in the development and utilization of the ALADIN numerical model to provide meteorological support of missions abroad. The department collaborates particularly with technically based institutes and universities, the Military Geographic and Hydrometeorological Office and the Czech Hydrometeorological Institute in research and development tasks.

2. Mathematical Modell Used in Decision-Making Process

Let us described the main task of one project solved nowadays at department of Military Geography and Meteorology. To verify the VAT the task of Cross Country Movement (CCM) was chosen as an example. It can be solved as a common problem or with consideration of certain types of vehicles (the most frequent or the weakest in the unit, but in case of armed forces usually off road vehicles). The detailed theory of CCM is in (Rybanský, 2009).The solution can offer to the commander not only one possibility, but the variants from which he can choose according to his intentions and the current situation at the given area. The particular parts of it are going to be used in the education process as a motivation for students.

2.1. Cross Country Movement

Let us recall the basis of the CCM theory. The main goal of CCM theory is to evaluate the impact of geographic conditions on of movement of vehicles in terrain. For the purpose of classification and qualification of geographic factors of CCM, it is necessary to determine:

- particular degrees of CCM

- typology of terrain practicability by kind of military (civilian) vehicles
- geographic factors and features with significant impact on CCM

As a result of the geographic factors impact evaluation we get three known degrees of CCM:

- GO - passable terrain
- SLOW GO - passable terrain with restrictions
- NO GO – impassable terrain

Geographic factors determining CCM and the selection of the access routes are follows:

- gradient of terrain relief, micro relief shapes
- vegetation cover
- soil conditions
- meteorological conditions
- settlements
- communications
- other natural and manmade object
- water sheets, water courses

The impact of given geographic factor can be evaluated as a coefficient of deceleration 'C_i' from the scale of 0 to 1. The coefficient of deceleration shows the real (simulated) speed of vehicle v_j in the landscape in the confrontation with the maximum speed of given vehicle v_{max}. The impact of the whole n geographic factors can be expressed as the formula:

$$v_j = v_{\max} \prod_{i=1}^{n} C_i, \quad n = 1, \dots, N. \tag{1}$$

The main coefficients of deceleration are listed in the next table.

Table 1 Main coefficients of deceleration

Basic coefficient	Geographic signification and impact
C_1	Terrain relief
C_2	Vegetation
C_3	Soils and soil cover
C_4	Weather and climate
C_5	Hydrology
C_6	Build-up area
C_7	Road network

Each coefficient consists of several coefficients of 2nd grade. The values of deceleration coefficients are counted for given vehicle (its technical properties) from ascertained properties of geog. objects stored in the spatial geodatabase.

2.2. Example

The vehicle can pass terrain step up to h_{max} high and trench up to w_{max} width, but the speed on this passable obstacles is reduced to one half of maximum speed. If the size of obstacle is bigger, the vehicle velocity is 0. Properties h_{max} and w_{max} are given by the technical description of given vehicles and comparative values are read from spatial geodatabase. In the mathematical formula the condition can be express:

$$C_{12} = \begin{cases} 0 & for \quad h > h_{\max} \\ 0 & for \quad w > w_{\max} \\ 0,5 & for \quad h \le h_{\max} \vee w \le w_{\max} \end{cases} \tag{2}$$

Using formula (1) it is possible to create a cost map in which the value of each pixel is the final (modelled) speed. The cost map can be as a source for the fastest path, reliable path etc. calculation.

2.3. Spatial database utility value evaluation

The master digital geographic data database is usually utilized as a base for spatial data analyses. The national or international databases are very detailed, carefully maintained and used in many applications. But nobody can suppose that those databases contain all information he could need.

The task of CCM solution could require more information that is available in the master database. Geographer-analyst has to consider which information and in what quality can he obtain from master database. E.g. for mentioned C12 coefficient it is necessary to select all microrelief obstacles in the area of interest (road and railway embankments, excavations, terrain steps, trenches etc.). Further he has to find out all their properties and their accuracy or count how many characteristics are missing. Next step is the individual functionality value of given part of master database evaluation. Through mathematical modelling it is then possible to solve tasks of the following types:

- how a change in a given partial parameter or parameters of a database is reflected in its total usability;
- which parameters need to be changed to achieve the required product functionality;
- which parameters may be “degraded” owing to the fact the product’s functionality is unnecessarily high.

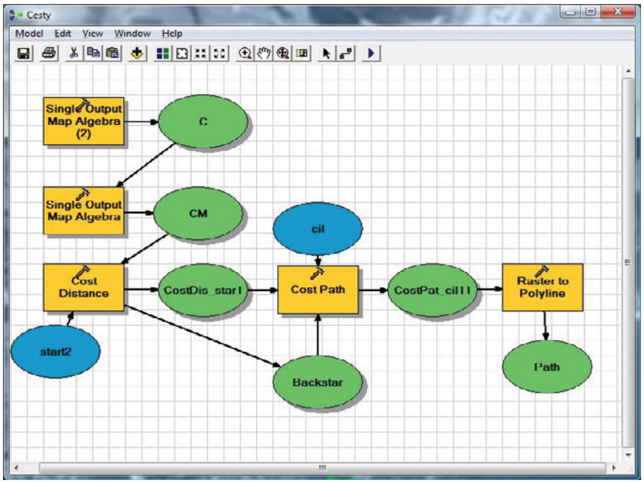

Figure 1. Road model

3. Model situation---Example

Above described procedure was used in the task “Finding the most beneficial route“. The main aim of this task was to judge several possible calculated paths for the military vehicle Tatra 815, see (Tatra, a.s. 2010). These paths were calculated in the „cost map (CM)“ based on the patency parameters for this type of vehicle.

In the experiment two versions of cost map were used. Map versions were created based on usable property changes of the database. Particularly, in this case we mean changes in topographic database, soil type database and digital elevation model. In our case the CM was created based on the parameters which evaluated influence of geographical factors for the cross-country movement of vehicles, published in (Rybanský, M. 2009). Values of final pixels in CM were given by aggregate function for calculation of deceleration coefficients, formula 3.2 in

(Rybanský, M. 2009). As mentioned before two versions of database were used – before and after update. The option before the update has only a limited number of filled thematic attribute concerning reliability

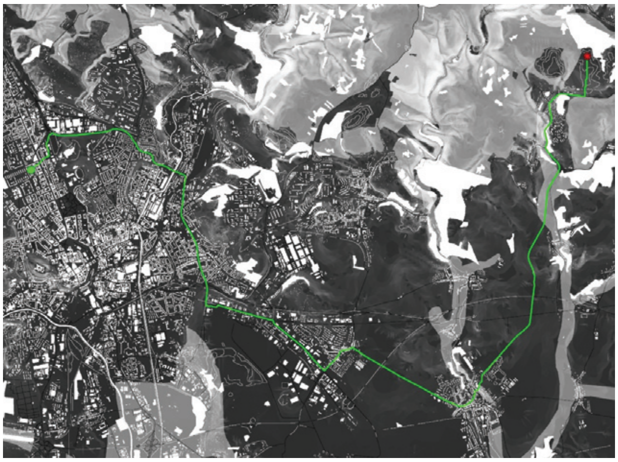

Figure 2. Cost map

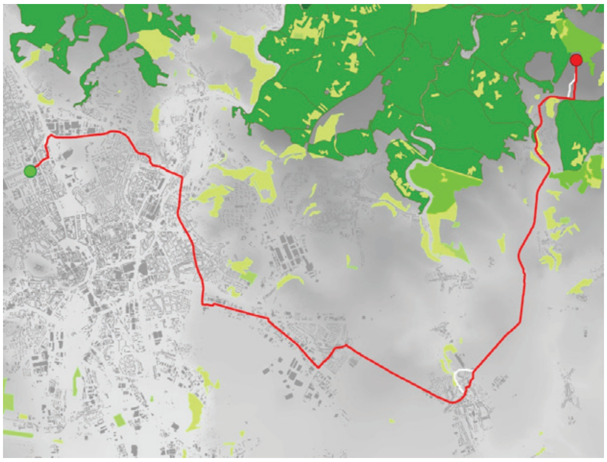

Figure 3. Search results the most suitable route for the vehicle

The ideal state of functional level is 1,0068 (i.e. performance standard). The positive change of database functionality cause higher costs necessary to ensure the data, e.g. the cost and time necessary to fill in the declared attributes. In the decision making process it raise an important question: *Were the resources spent efficiently with respect to the increase reliability of the suggested path?*

Theoretically, all calculated routes can be used. But with less data, not reliable data, etc. is more risky, so the commander assumes the risk that the vehicle cannot be able to overcome the obstacle on the selected road. In other cases the probability of correct decision is high, so the vehicle should not get into trouble with overtaking of obstacles. This simple example was chosen only for comparing how the database functionally and reliability of decision making process matched together. In the complex evaluation is necessary to evaluate the impact of all terrain features in the area on cross country mobility.

4. Conclusion

The proposed solution aims to streamline the activities associated with the use of inhomogeneous data and information systems, command and control so that operational components should be available not only its own database, as well as relevant documentation about the quality and reliability of data used. Based on this information they can in their decisions to work with those documents and where appropriate their decisions correct.

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